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# Objectives and Procedures for A Study of Spray Irrigation of Dairy Wastes \*

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In a recent paper McKee<sup>1</sup> summarized the results obtained from the spray irrigation of dairy wastes at eight typical installations. It is of interest to note that this method of disposal for milk wastes has been in use for about the past eight years. Spray irrigation for the disposal of cannery wastes has a somewhat longer history. A number of articles on this subject have appeared in the literature, and many have been presented at the Purdue Industrial Waste conferences.<sup>2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17</sup> Since, a review of the literature on this subject has been made by Erickson<sup>18</sup> it is not considered necessary to present a detailed review in this paper.

In summarizing the data presented in the previous articles noted above, however, it was observed that for both cannery and dairy wastes, application rates, as well as BOD loadings have varied over a wide range.

Inasmuch as spray irrigation appears to hold promise as an effective means for the disposal of wastes from dairy plants in view of the encouraging results already reported in the literature, and since the method is likely to be particularly useful for small plants in areas where land is available, a Research and Marketing Act

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contract between the University of Wisconsin and the United States Department of Agriculture was made. The purpose of the study is to determine the effectiveness of spray irrigation as a method for the disposal of dairy plant wastes. The project includes studies of both the soils and engineering aspects of the problem.

The initial emphasis has been to observe existing spray irrigation procedures and facilities in milk products factories located in central Wisconsin. The second and final phase of the project is to evaluate this method, and if warranted, make recommendations on the proper installation and operation of spray irrigation as a method of disposal for dairy wastes. These recommendations will be based on results obtained in the initial phase of the project through the observation of the existing sites. With the conclusion of the winter and subsequent thawing conditions, it is felt that sufficient time will have lapsed for the initial observation period of study. From then on, various application rates will be considered on particular soil types, in conjunction with a rigorous study of resulting effects on the soil.

Since the amount of water that can be applied to any given area depends on certain specific soil properties as well as on the water consumed by the crop, the sites for the study were carefully selected so as to provide a wide range of soil conditions. In this regard consultation was had with a representative of the Committee on Water Pollution of the State of Wisconsin, because at certain of the installations variations in operation of the irrigation systems may be required during certain phases of the project.

At each of the installations, a topographical survey is made of the disposal area. The maps are used to indicate location of spray equipment and to show variation in topography at each site and to permanently locate soil borings as this type of survey is made.

Six sites have been selected.

#### DESCRIPTION OF SOILS

Description of soils being irrigated by the factory included in this study are as follows:

The soil types irrigated at Plant A vary from Miami to Dodge silt loams. The surface soil is a friable silt loam and grades into a more dense clay loam in the subsoil. A calcareous sandy till occurs at a depth varying from 18 in. (Miami) to over 3 ft. (Dodge). The amount of water in excess of crop needs that can be applied to this soil is dependent upon the permeability of the subsoil.

At Plant B the field being irrigated is flat bottom land. Several feet of recent deposit derived from the upland cultivated fields overlies the old soil. The texture of the surface 2 ft. varies from sandy loam to silt loam which grades into a sand or sandy loam below. Peat occurs at a depth of about 4 ft. This soil has a high permeability.

The soil irrigated at the Plant C is Hixton sand loam. The surface 2 ft. consists of sandy loam which is underlain by sand grading into decomposing sandstone. Water movement through this soil is good.

The field irrigated at Plant D lies only a few feet above the water level of a near-by creek. Consequently, the water table is only a few feet below the surface in much of the field, and in some of the depressional areas standing water occurs at least during part of the year. The soil is derived from eroded material from the surrounding uplands. There is a silt loam cap varying in depth from 6 to 12 in. which is underlain by loam. The subsoil is mottled and bluish gray in color indicating water logged conditions. This site was selected because of its poor irrigation possibilities.

At Plant E the field irrigated is Dodge silt loam. The surface soil, 8 to 10 in. thick, is a dark silt loam. The subsoil, which varies from 18 in. to 2 ft. in depth, is a silty clay loam. Below this is a layer of compacted clay which grades into broken limestone rock. Solid rock occurs at a depth varying from 4 to 5 ft. Since this is a fairly shallow soil overlying solid rock, water logging can become a problem under intense irrigation.

Soil at Plant F is of organic origin.

To relate the soil properties to the irrigation results obtained at the different sites, chemical and physical data are being obtained on the irrigated and unirrigated soils at each site. The chemical composition of the waste waters at each plant is also being determined since certain materials may be present in sufficient quantity to have an important effect on the crop or soil. Nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium are of benefit to the crop, whereas boron if present in too great a concentration is distinctly toxic. Sodium if applied in too great a quantity causes deflocculation of silt loam or clay soil, which greatly reduces its permeability.

The physical measurements being made on each of the soil horizons to the depth of till or bedrock are: soil texture (percentage of sand, silt, and clay), water and air permeability, stability of the

soil aggregates, field moisture capacity, bulk density, and pore size distribution.

Data obtained from the chemical and physical measurements will be useful in determining the long time effects on the soil of milk plant wastes, and the amount of wastes that can be safely applied to different kinds of soils for given climate and crop conditions.

#### RESULTS AND DISCUSSION

To date, available phosphorus, chlorides and exchangeable potassium, calcium, magnesium, and sodium have been determined for both the irrigated and unirrigated soils. Measurements of the soil properties have not been completed.

The results of the chemical changes brought about by irrigation with milk plant wastes are given in Table I. Since the results from any one site were not typical of all other sites, the data from all sites were averaged to give a general picture of the trends encountered thus far.

Although soil pH does not appear to be appreciably affected by irrigation with milk plant waste, it may be increasing slightly due to waste application. It is also possible that since the differences between the irrigated and unirrigated soils are small, they may be due entirely to the variations in sampling sites. As is to be expected, the soluble chlorides in the soil increased considerably with irrigation. The amounts found in the soil are only a fraction of those applied because the chlorides are not held by the soil, and therefore, are rapidly carried out by percolating water. The amounts present in the irrigated soils were well below harmful levels. Boron has not been found to be present in toxic amounts.

Available soil phosphorus increased appreciably with irrigation only in the top 6 in. of soil. This was expected, because, on contact with the soil, most of the phosphorous reverts to insoluble or only slightly soluble forms. It appears that the main source of phosphorus in the waste is tri-sodium phosphate which is used as an emulsifying agent in the factories.

Accumulation and movement of exchangeable potassium in the irrigated soils varied with conditions at the irrigation sites. This variation is attributed to the potassium content of the waste, the amount of waste applied, and the amount and type of clay minerals present in the soil. At one site a four-fold increase in exchangeable potassium in the top soil occurred, and downward movement through the entire profile was noted, while at another location a slight increase in exchangeable potassium was detected only in the top soil.

TABLE 1. INFLUENCE OF MILK PLANT WASTE ON EXCHANGEABLE, WATER SOLUBLE, AND ACID SOLUBLE IONS IN THE SOIL.<sup>1</sup>

Soils	ppm				ppm				ppm Exchangeable							
	pH		Acid Sol. P		Water Sol. Cl		K		Ca		Mg		Na			
Depth	I	U	I	U	I	U	I	U	I	U	I	U	I	U		
Inches	I	U	I	U	I	U	I	U	I	U	I	U	I	U		
0-6	6.79	6.57	84.7	45.6	131.8	17.9	209.2	105.3	2265	2301	562.7	474.5	213.6	54.2		
6-12	6.50	6.13	48.6	36.9	90.2	14.6	113.8	98.5	1689	1634	421.3	428.6	143.2	40.8		
12-18	6.13	5.88	42.9	30.8	107.0	19.3	125.0	111.5	1585	1405	396.0	392.7	122.4	31.5		
18-24	5.88	5.68	44.5	38.1	70.0	41.2	180.2	115.5	1338	1522	387.0	464.5	86.7	41.9		
24-30	5.70	5.60	47.6	33.0	92.0	26.9	136.0	125.7	1371	1471	368.8	468.8	87.0	31.0		

<sup>1</sup> Average of results from all sites.

### I—Irrigated.

## U—Unirrigated.

The distribution of exchangeable calcium and magnesium varied with conditions and soils at the specific locations. Because of the large amount of calcium and magnesium present in the soil and, in comparison, the relatively small amounts added by irrigation; it is impossible to note any definite trends.

An increase in exchangeable soil sodium was found at all sites. The extent of sodium accumulation and leaching varied with soil characteristics and the rate of application. At one site, there was an increase of exchangeable sodium in the top soil only, while at the other sites increased quantities of sodium were found in the entire profile. Generally, the increase in exchangeable sodium was found in largest quantity in the top soil and this amounted to as much as 450 ppm in one case. At the other sites sodium in the soil is accumulating at a much slower rate, as is indicated by the average for all sites. A much longer period of irrigation will be needed to determine the long-time effects of the sodium accumulation on the soil.

#### GENERAL DATA AT EACH SITE

A rain gauge and thermometer are located at each site so that precipitation and temperature records can be obtained.

For each plant a check list has been made and information received, on the following items:

1. Date data received
2. Name of plant
3. Location of plant
4. Amount of each product produced
5. Amount of milk intake  
Amount of cream intake
6. Type of equipment and capacity:  
Can washer; holding tank; cheese vats; butter churners; ice cream machines; coolers; curing tanks; and cream separators.
7. Floor space of plant
8. Depth of well and type of system  
Composition of water
9. Cost of irrigation system
10. Arrangement utilized to secure land for the irrigation project
11. Compounds and their composition as used in each plant:  
Soap; detergents; scouring compounds; and curing aids.
12. Schedule of plant operation

Supplementary information regarding the irrigation system has also been obtained for the sites under study. Included in these data are the following items: Size of wet well or sump; type of pump and motor used; piping used for that portion of system that is permanently fixed; type of irrigation piping and valving arrangement; and number, size, type, and spacing of spray nozzles.

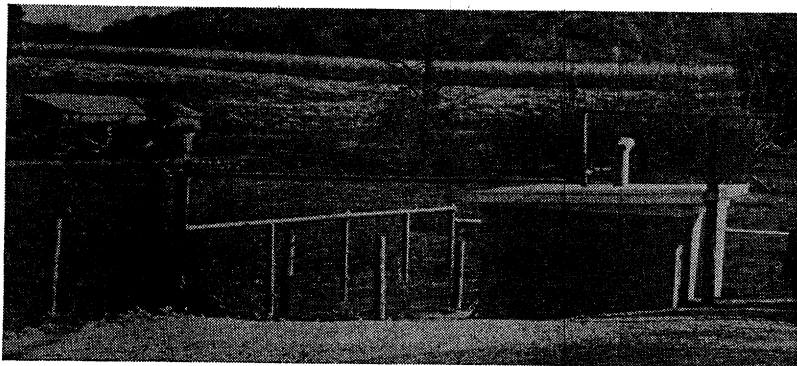
A diagrammatic sketch of the sump and piping are made a part of the record being maintained.

One of the pumping station installations is shown in the accompanying photograph, Figure 1. The irrigation field is adjacent to the pump station. It is of interest to note that in this installation the operator had decided to mount the irrigation pipe on posts. This was done because of the presence of livestock in the field at times.

An interior view of this installation is shown in Figure 2. The self-priming centrifugal pump is on the left. Near the center is the sampler and refrigeration box in which composite samples of the waste are collected.

#### SURVEY PROCEDURE

The first step in the survey procedure was to devise flow measurement and sampling apparatus. At each installation the pump is activated by a float switch operating in a wet well. When the pump is in operation the discharge to the irrigation system is essentially constant. Therefore, it is possible to measure the total flow to the irrigation field by determining (1) the period of time in hours, minutes, and seconds that the pump is in operation each day and (2) the discharge characteristics of the pump under the operating head.



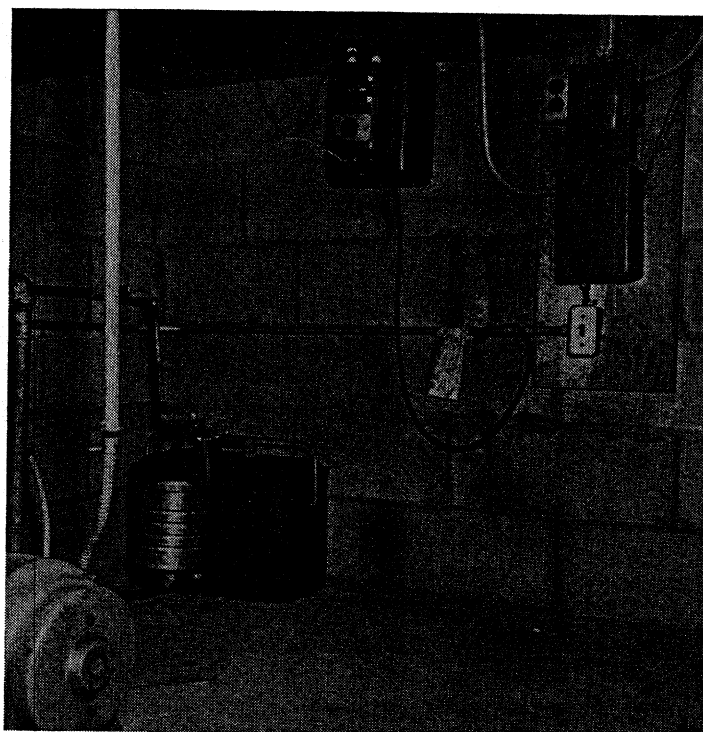


FIGURE 2.  
*Interior of pump house.*

To obtain the pumping time an electric clock has been installed across the line supplying power to the pump. Each time the pump operates the clock starts, and the cumulative time of operating is recorded. The hours, minutes, and seconds are recorded daily and noted on a log sheet by each plant proprietor. Each day the operator sets the clock to 12 o'clock after having recorded the reading for the previous day. The rate of discharge for the system is checked by making a time-weight measurement at the spray nozzles, and by measuring volumetrically the amount removed from the sump.

The clocks and the log sheet are housed in a small cabinet installed on or adjacent to the pump house. See Figure 3.

In addition to recording the time the pump is in operation the plant operator records daily the information that is indicated on a log sheet.

The equipment devised and in use for the collection of composite samples is described below. Galvanized piping connected to

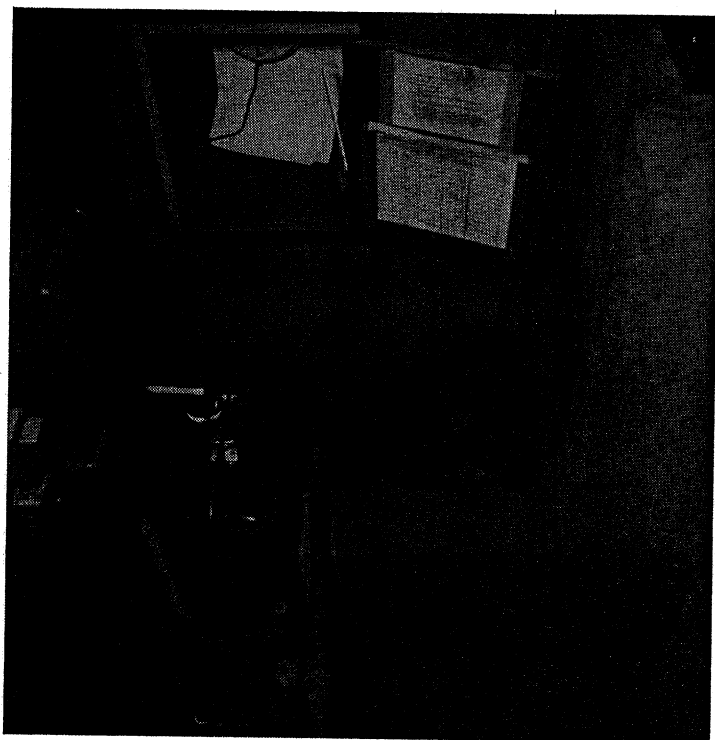


FIGURE 3.  
*View of cabinet showing clock and log sheets.*

the discharge side of the pump terminates above a deflecting plate at the sampling box. Attached to the plate is a small trough which leads to a funnel which in turn discharges to a 2-liter sample collection bottle which is housed in a small "picnic-type" ice box. The amount of sample collected can be adjusted by adjusting the slope of the trough which is free to rotate through a vertical arc. Only a small portion of the waste that is discharged on the splash plate enters the trough. The excess falls into a bucket which has a bottom opening. This opening is connected to a pipe which returns the excess waste to the sump or wet well. Figure 2.

With the arrangement in use clogging in the sampling system has been practically eliminated. The method provides a representative sample of the waste that is being used as irrigation water. Inasmuch as the discharge from the pump is constant the sample is obtained at a constant rate.

In addition to the 24-hour composite samples that are being obtained in the manner outlined above, surveys are also being made on

a 24-hour basis in which samples are being obtained at one-hour intervals. The purpose of these latter surveys is to make an evaluation of the variation in the composition of the waste on a time interval basis. Later surveys will be made at each plant which will cover the more critical hours of daily operation. These surveys, however, will be more intensive in nature in that 1/2 or even 1/4 hour intervals will be used where wide hourly variations have been observed on the earlier 24-hour survey. In this way any discharge of waste of unusual composition will be detected, and a knowledge of diurnal variations will be obtained.

Analyses on the wastes from both the 24-hour composite sampling and time interval sampling are being made. Included in the determinations are or will be the following: pH, five-day BOD; COD; temperature; solids; total organic nitrogen; ammonia nitrogen; potassium; sodium; magnesium; calcium; phosphorus; and chlorides.

Some typical data as to waste composition obtained thus far are given in Table II.

#### DISCUSSION OF WINTER OPERATION

Persistence of above freezing temperatures late into October 1956 enabled the operators to irrigate without immediate drainage after pumping. It is important during freezing weather to insure that the pipelines are self-draining. The desired self-draining feature is lost if the pipe sags between supports. If the sag is appreciable, the undrained water will freeze and block at least a portion of the cross sectional area of the pipe and, at worst, rupture the pipe.

In some instances it is necessary immediately after pumping for the operator to uncouple the pipe and allow the system to drain. The pipe couplings used on four of the project sites are supposed to be self-draining. The coupling has a rubber flange on one end which is supposed to seal under pressure and open when the pump is not operating. Actually, if the pipe sections are not off center, the drainage from these couplings is too slow to prevent freezing in the pipelines.

On November 10, 1956, the sprinkler system at one location was moved to a permanent winter setup. Although the line is situated on an uphill slope (grade 15 per cent) the piping was placed on posts to eliminate any sagging which might result if the piping were on the ground. Elevating the piping off the ground also prevents snow and the developing ice cap from burying the line and sprinkler nozzles. The piping is elevated 2 to 6 ft. off the ground.

TABLE II. PERTINENT DATA ON WASTE VOLUME AND COMPOSITION FROM  
THREE INSTALLATIONS

Factory	Cost	Milk Intake lbs/day	Waste Volume gals/day	Actual Application Rates in/hr	(1) BOD loading lbs. per acre per day	pH	Total Nitrogen ppm	Sodium ppm	K ppm	Ca ppm	Mg ppm	P ppm	Cl ppm
B	\$1550	10,000 to 30,000	1120	0.112	152	4.95	198	375	130	71	38	56	378
C	2300	20,000 to 47,000	5660	0.286	134	7.1	88	405	26	69	40	25	527
D	1100	6,200 to 15,000	755	0.130	122	6.3	386	354	80	74	38	136	230

Note: Disposal areas used are from 0.5 to 3 acres approximately.

(1) Applied for periods ranging from 0.75 to 2.4 hours each day.

(2) BOD concentrations vary over a range of from 925 to 3680 ppm (Average five-day value).

When the system is to be used in the winter, the float switch control is no longer used and the system is manually operated. The sump is practically emptied each day with one continuous pumping and the line is drained.

The waste is pumped each day between 12 noon and 2 p.m. By the time the daily flow has been pumped, most of the washing operation in the plant has been completed. Waste held over to the next day is then minimized. Most important is the fact that the maximum temperature of the day is reached during this period. Not only is it important to pump in the early afternoon, because it is the warmest part of the day, but loss of moisture to the air during spraying at this time will be at a maximum.

Lower temperatures make daily storage of the waste flow possible. In the summer, waste should be pumped periodically during the day to avoid putrefaction in the sump. Aside from the threat of freezing, this is the greatest difference between winter and summer operation.

One problem encountered at the project sites in weather at temperatures of near-zero degrees Fahrenheit is the freezing of nozzles. The warm waste (24°C) will keep water moving through the nozzles, however, the rotation in some cases has stopped. The force from the jet on the impinging spring lever of the nozzle is unable to counteract increased friction in moving parts in the stem of the sprinkler at lower temperatures. The result is application of waste in one spot, rather than in a circular area. During 0°F weather, the nozzles must be checked for clogging during the pumping operation. If the nozzle is clogged for any length of time, freezing and rupture of the pipeline is likely to occur. The end nozzles will clog first. The impingers can be removed from the nozzle to decrease clogging.

On November 20, the initial snowfall of the winter covered the disposal areas. The waste melted the snow, as evidenced by a circular area coincidental with the spraying area. This condition existed for several days and gradually, an ice cap began to form in the same circular areas. On November 27, ice caps were 1-1/2 to 2 in. thick. Near the nozzles the ice cap would support a 180 lb person walking on the cap.

A warm spell for two days prior to December 4 melted the ice cap and partially thawed the ground.

By January 3, the ice cap had formed again. During weather when temperatures are well below freezing there is very little run-

off as the waste freezes soon after touching the ground. At warmer temperatures the water forms a channel in the ice which gradually closes and forms a miniature glacier or delta as the waste begins to freeze.

By early February the depth of ice cap approached 18 in. ; however, no appreciable runoff was noted.

Other than ice cap growth, little can be said at this time about effects of irrigation of dairy wastes on various types of soil during the winter.

At the present time observations on soil reactions are being made. By March 13, 1 ft. of ice sheet remained. By March 27 a porous sheet of about 3 in. remained. By April 10, the ice cap had disappeared.

In summary, it is possible, through careful attendance, to operate successfully a spray irrigation system throughout the winter. It appears that some of the grass remained alive on the sloped areas. How well this fills in is to be determined.

#### GENERAL OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

As a result of the work thus far the following comments regarding the study are made:

1. The cost of the systems varies from \$400 to \$2,300.
2. Although some data were given in the literature review, application rates at dairy plants mentioned are generally lower than those under study in the project. Application rates given for canneries in the review compare closely with the rates at the cheese factories in the project.
3. From the ratio of volatile solids to total solids, certain relationships can be made which characterize each plant waste. Two of the plants have high volatile to total solids ratios. This, of course, infers that the organic content of the waste is high. This is substantiated by the relatively high (five-day) BOD test results at both plants. Two other plants show lower BOD and lower volatile solids content. These systems both have receiving chambers separate from the sump. The settling out of heavier organic matter in this chamber could explain the lower values.

From field studies, the following observations have been made:

1. The sump should be designed to hold the maximum daily flow.
2. Where the cover crop is to be cut, a week to ten days is necessary to dry the field for cutting and baling for storage.

3. A small insulated hut is necessary to protect the motor and to shelter the waste from heat and cold.

4. Two screening units are desirable. Where a receiving chamber exists, the units may be placed at the inlet end of both the receiving chamber and sump. Maximum mesh size should be 1/4 in. The screens should be cleaned daily.

5. Some differences exist in theory of designing a smaller and larger spray irrigation disposal system. McCulloch and Schrunk<sup>19</sup> state that if waste disposal is to be accomplished by spray irrigation, small nozzle openings operating at high pressures should be used. This will effect a mist, which will cause a greater amount of waste to evaporate. From observation it is known that the solids in the waste will clog any small nozzle openings. It is not economically possible to effect the high degree of solids removal necessary for such a condition.

6. The sump should be flushed out monthly. More frequent flushings may be necessary in summer. For cleaning and back drainage purposes, it is desirable to place a tee and valve on the discharge side of the pump. In this way, any vertical section of pipe leading from the motor enclosure can be drained. Otherwise, during the winter the short column of water would freeze and block the pipe.

As previously mentioned, the sump must be flushed out periodically. This can be done by attaching a hose and nozzle to the outlet in the tee. The applied pressure will dislodge any scum or growth which might accumulate on the walls or floor of the sump. Fat accumulates in a thick layer on the sides of the sump.

7. The flow line of the pump should be at the same elevation as the lowest water level of the sump. In this way loss of pump prime will be avoided.

8. Care should be taken in waterproofing the interior of the sump with a material which is at least resistant to 100°F temperatures. The cooling water which enters the sump is sometimes hotter than this, but the effect of dilution would prevent any great amount of deformation of coating.

9. An important feature of construction is the slope of the bottom of the sump. For complete drainage, the slope is necessary. A small pit for the suction line will make better drainage possible.

10. A small grit chamber preceding the sump would be desirable. The narrow channel should be designed so that particles now accumulating in the bottom of the sump will be easier to re-

move. A grit chamber would effect greater removal of solids and thereby lessen chance of nozzle clogging.

11. The average daily flow variation to the sump should be observed. The float switch should be set to regulate the water level so that the sump is empty after the daily washing operation. In this way the overnight flow of the relatively pure cooling water will dilute residual scum waste and prevent any lactic acid action on the concrete.

12. One problem which exists throughout the year, but which is more intense in winter, is one of condensation. During early morning hours in the summer and at all times in the winter, the warm waste evaporates and condenses on the ceiling of the sump. If the floor opening to the sump is not watertight this condensation will carry up onto the insulation where the motor is enclosed above the sump.

More critical, is corrosion of the float switch and electrical contacts. In all cases, the float switch is located in or above the sump. To avoid condensation problems, the float switch should be placed outside of the sump. A float and lever mechanism would be the simplest arrangement. Also, a watertight cover should be placed over the sump opening to protect the insulation in the hut. If appreciable moisture is still present, a small electric heater may be necessary.

13. To prevent scum formation in the irrigation line, permanent, elevated support would permit daily drainage.

14. If available, the disposal site should be located so that prevailing wind will blow odor and fine spray away from the cheese factory.

15. With careful attendance provided, from a mechanical standpoint, winter operation of spray irrigation systems in central Wisconsin is possible. Effects on soil and cover crop are yet to be studied.

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